

CLAIMS

What is claimed is:

- 1 1. A method for processing data received from a communications channel comprising
2 the computer-implemented steps of:
3 receiving, from the communications channel, received data that is based upon both
4 modulated data and noise, wherein the modulated data is the result of original
5 data modulated onto one or more carriers;
6 equalizing the received data to generate equalized data, wherein the equalizing is
7 performed using an algorithm with a set of one or more coefficients selected
8 based on noise power and an impulse response of the communications
9 channel; and
10 recovering an estimate of the original data by demodulating the equalized data.
- 1 2. The method as recited in Claim 1, wherein the set of one or more coefficients is
2 selected to optimize an impulse response length of the communications channel to
3 reduce interference.
- 1 3. The method as recited in Claim 2, wherein the interference includes inter-symbol
2 interference.
- 1 4. The method as recited in Claim 2, wherein the interference includes inter-channel
2 interference.
- 1 5. The method as recited in Claim 1, wherein the set of one or more coefficients is
2 selected to reduce the noise power.
- 1 6. The method as recited in Claim 5, wherein the set of one or more coefficients is
2 selected to minimize noise power.
- 1 7. The method as recited in Claim 1, wherein the set of one or more coefficients is
2 selected to simultaneously optimize an impulse response length of the
3 communications channel to reduce interference and reduce the noise power.

- 1 8. The method as recited in Claim 1, wherein a cyclic prefix is added to the modulated
2 data and the set of one or more coefficients is selected to ensure that an impulse
3 response of the communications channel and a device that performs the step of
4 equalizing is less than a length of the cyclic prefix.
- 1 9. The method as recited in Claim 1, wherein the set of one or more coefficients is
2 selected to reduce the noise power due to inter-symbol interference, inter-channel
3 interference, and noise from one or more additional interference sources.
- 1 10. The method as recited in Claim 9, wherein the one or more additional interference
2 sources includes at least one interference source selected from the group consisting of
3 crosstalk, amplitude-modulated signals, and white Gaussian noise.
- 1 11. The method as recited in Claim 1, wherein the set of one or more coefficients are
2 selected by minimizing a function of communications channel impulse response and
3 noise power.
- 1 12. The method as recited in Claim 1, wherein the set of one or more coefficients are
2 selected based on a noise power spectral density.
- 1 13. The method as recited in Claim 1, wherein the step of equalizing the received data
2 includes processing the received data using a finite impulse response (FIR) filter.
- 1 14. The method as recited in Claim 13, wherein the received data is modulated using
2 discrete multitone modulation and a set of one or more (FIR) coefficients for the FIR
3 filter is selected to minimize noise power and optimize impulse response length of the
4 communications channel to reduce interference.
- 1 15. The method as recited in Claim 1, wherein the communications channel is a twisted
2 pair telephone line.
- 1 16. The method as recited in Claim 1, wherein the twisted pair telephone line uses a
2 transmission protocol selected from the group consisting of Asymmetric Digital
3 Subscriber Line (ADSL), G.Lite and Very High Bit Rate DSL (VDSL).

- 1 17. A method for determining coefficients for use in a filter to process data received from
2 a communications channel comprising the computer-implemented steps of:
3 determining a communications channel transfer function based on the received data;
4 determining a noise power spectral density based on the received data;
5 determining a communications channel impulse response based on the
6 communications channel transfer function;
7 determining a noise covariance based on the noise power spectral density; and
8 determining the coefficients based on the communications channel impulse response
9 and the noise covariance.
- 1 18. The method as recited in Claim 17, wherein the step of determining the
2 communications channel transfer function includes the computer-implemented steps
3 of:
4 accumulating a plurality of symbol values based on the received data;
5 determining an average received symbol value based on the received data; and
6 determining the communications channel transfer function based on the plurality of
7 symbol values and the average received symbol value.
- 1 19. The method as recited in Claim 17, wherein the step of determining the noise power
2 spectral density includes the computer-implemented steps of:
3 measuring a plurality of symbol values based on the received data;
4 determining an average received symbol value based on the received data; and
5 determining the noise power spectral density based on the plurality of symbol values
6 and the average received symbol value.
- 1 20. The method as recited in Claim 17, wherein the step of determining the
2 communications channel impulse response includes the computer-implemented step
3 of:
4 determining the communications channel impulse response based on an inverse fast
5 Fourier transform (FFT) of the communications channel transfer function.

- 1 21. The method as recited in Claim 17, wherein the step of determining the noise
2 covariance includes the computer-implemented step of:
3 determining the noise covariance based on an inverse fast Fourier transform (FFT) of
4 the noise power spectral density.
- 1 22. The method as recited in Claim 17, wherein the step of determining the coefficients
2 includes the computer-implemented steps of:
3 forming two matrices based on the communications channel impulse response and the
4 noise covariance;
5 generating a quadratic expression based on the two matrices; and
6 minimizing the quadratic expression to determine the coefficients.
- 1 23. A computer-readable medium carrying one or more sequences of instructions for
2 processing data received from a communications channel, wherein execution of the
3 one or more sequences of instructions by one or more processors causes the one or
4 more processors to perform the steps of:
5 receiving, from the communications channel, received data that is based upon both
6 modulated data and noise, wherein the modulated data is the result of original
7 data modulated onto one or more carriers;
8 equalizing the received data to generate equalized data, wherein the equalizing is
9 performed using an algorithm with a set of one or more coefficients selected
10 based on noise power and an impulse response of the communications
11 channel; and
12 recovering an estimate of the original data by demodulating the equalized data.
- 1 24. The computer-readable medium as recited in Claim 23, wherein the set of one or
2 more coefficients is selected to optimize an impulse response length of the
3 communications channel to reduce interference.
- 1 25. The computer-readable medium as recited in Claim 24, wherein the interference
2 includes inter-symbol interference.

- 1 26. The computer-readable medium as recited in Claim 24, wherein the interference
2 includes inter-channel interference.
- 1 27. The computer-readable medium as recited in Claim 23, wherein the set of one or
2 more coefficients is selected to reduce the noise power.
- 1 28. The computer-readable medium as recited in Claim 27, wherein the set of one or
2 more coefficients is selected to minimize noise power.
- 1 29. The computer-readable medium as recited in Claim 23, wherein the set of one or
2 more coefficients is selected to simultaneously optimize an impulse response length
3 of the communications channel to reduce interference and reduce the noise power.
- 1 30. The computer-readable medium as recited in Claim 23, wherein a cyclic prefix is
2 added to the modulated data and the set of one or more coefficients is selected to
3 ensure that an impulse response of the communications channel and a device that
4 performs the step of equalizing is less than a length of the cyclic prefix.
- 1 31. The computer-readable medium as recited in Claim 23, wherein the set of one or
2 more coefficients is selected to reduce the noise power due to inter-symbol
3 interference, inter-channel interference, and noise from one or more additional
4 interference sources.
- 1 32. The computer-readable medium as recited in Claim 31, wherein the one or more
2 additional interference sources includes at least one interference source selected from
3 the group consisting of crosstalk, amplitude-modulated signals, and white Gaussian
4 noise.
- 1 33. The computer-readable medium as recited in Claim 23, wherein the set of one or
2 more coefficients are selected by minimizing a function of communications channel
3 impulse response and noise power.
- 1 34. The computer-readable medium as recited in Claim 23, wherein the set of one or
2 more coefficients are selected based on a noise power spectral density.

1 35. The computer-readable medium as recited in Claim 23, wherein the instructions for
2 equalizing the received data further comprise instructions which, when executed by
3 the one or more processors, cause the one or more processors to carry out the step of
4 processing the received data using a finite impulse response (FIR) filter.

1 36. The computer-readable medium as recited in Claim 35, wherein the received data is
2 modulated using discrete multitone modulation and a set of one or more (FIR)
3 coefficients for the FIR filter is selected to minimize noise power and optimize
4 impulse response length of the communications channel to reduce interference.

1 37. The computer-readable medium as recited in Claim 23, wherein the communications
2 channel is a twisted pair telephone line.

1 38. The computer-readable medium as recited in Claim 23, wherein the twisted pair
2 telephone line uses a transmission protocol selected from the group consisting of
3 Asymmetric Digital Subscriber Line (ADSL), G.Lite and Very High Bit Rate DSL
4 (VDSL).

1 39. A computer-readable medium carrying one or more sequences of instructions for
2 determining coefficients for use in a filter to process data received from a
3 communications channel, wherein execution of the one or more sequences of
4 instructions by one or more processors causes the one or more processors to perform
5 the steps of:
6 determining a communications channel transfer function based on the received data;
7 determining a noise power spectral density based on the received data;
8 determining a communications channel impulse response based on the
9 communications channel transfer function;
10 determining a noise covariance based on the noise power spectral density; and
11 determining the coefficients based on the communications channel impulse response
12 and the noise covariance.

1 40. The computer-readable medium as recited in Claim 39, wherein the instructions for
2 determining the communications channel transfer function further comprise
3 instructions which, when executed by the one or more processors, cause the one or
4 more processors to carry out the steps of:
5 accumulating a plurality of symbol values based on the received data;
6 determining an average received symbol value based on the received data; and
7 determining the communications channel transfer function based on the plurality of
8 symbol values and the average received symbol value.

1 41. The computer-readable medium as recited in Claim 39, wherein the instructions for
2 determining the noise power spectral density further comprise instructions which,
3 when executed by the one or more processors, cause the one or more processors to
4 carry out the steps of:
5 measuring a plurality of symbol values based on the received data;
6 determining an average received symbol value based on the received data; and
7 determining the noise power spectral density based on the plurality of symbol values
8 and the average received symbol value.

1 42. The computer-readable medium as recited in Claim 39, wherein the instructions for
2 determining the communications channel impulse response further comprise
3 instructions which, when executed by the one or more processors, cause the one or
4 more processors to carry out the step of:
5 determining the communications channel impulse response based on an inverse fast
6 Fourier transform (FFT) of the communications channel transfer function.

1 43. The computer-readable medium as recited in Claim 39, wherein the instructions for
2 determining the noise covariance further comprise instructions which, when executed
3 by the one or more processors, cause the one or more processors to carry out the step
4 of:
5 determining the noise covariance based on an inverse fast Fourier transform (FFT) of
6 the noise power spectral density.

1 44. The computer-readable medium as recited in Claim 39, wherein the instructions for
2 determining the coefficients further comprise instructions which, when executed by
3 the one or more processors, cause the one or more processors to carry out the steps of:
4 forming two matrices based on the communications channel impulse response and the
5 noise covariance;
6 generating a quadratic expression based on the two matrices; and
7 minimizing the quadratic expression to determine the coefficients.

1 45. An apparatus for processing data received from a communications channel
2 comprising:
3 an equalizer configured to equalize received data from the communications channel
4 and generate equalized data, wherein the received data is based upon both
5 modulated data and noise, and the modulated data is the result of original data
6 modulated onto one or more carriers, and wherein the equalizer is configured
7 to use an algorithm with a set of one or more coefficients selected based on
8 noise power and an impulse response of the communications channel; and
9 a demodulator configured to generate an estimate of the original data by
10 demodulating the equalized data.

1 46. The apparatus as recited in Claim 45, wherein the set of one or more coefficients is
2 selected to optimize an impulse response length of the communications channel to
3 reduce interference.

1 47. The apparatus as recited in Claim 46, wherein the interference includes inter-symbol
2 interference.

1 48. The apparatus as recited in Claim 46, wherein the interference includes inter-channel
2 interference.

1 49. The apparatus as recited in Claim 45, wherein the set of one or more coefficients is
2 selected to reduce the noise power.

- 1 50. The apparatus as recited in Claim 49, wherein the set of one or more coefficients is
2 selected to minimize noise power.
- 1 51. The apparatus as recited in Claim 45, wherein the set of one or more coefficients is
2 selected to simultaneously optimize an impulse response length of the
3 communications channel to reduce interference and reduce the noise power.
- 1 52. The apparatus as recited in Claim 45, wherein a cyclic prefix is added to the
2 modulated data and the set of one or more coefficients is selected to ensure that an
3 impulse response of the communications channel and the equalizer is less than a
4 length of the cyclic prefix.
- 1 53. The apparatus as recited in Claim 45, wherein the set of one or more coefficients is
2 selected to reduce the noise power due to inter-symbol interference, inter-channel
3 interference, and noise from one or more additional interference sources.
- 1 54. The apparatus as recited in Claim 53, wherein the one or more additional interference
2 sources includes at least one interference source selected from the group consisting of
3 crosstalk, amplitude-modulated signals, and white Gaussian noise.
- 1 55. The apparatus as recited in Claim 45, wherein the set of one or more coefficients are
2 selected by minimizing a function of communications channel impulse response and
3 noise power.
- 1 56. The apparatus as recited in Claim 45, wherein the set of one or more coefficients are
2 selected based on a noise power spectral density.
- 1 57. The apparatus as recited in Claim 45, wherein the equalizer is configured to process
2 the received data using a finite impulse response (FIR) filter.
- 1 58. The apparatus as recited in Claim 57, wherein the received data is modulated using
2 discrete multitone modulation and a set of one or more (FIR) coefficients for the FIR
3 filter is selected to minimize noise power and optimize impulse response length of the
4 communications channel to reduce interference.

1 59. The apparatus as recited in Claim 45, wherein the communications channel is a
2 twisted pair telephone line.

1 60. The apparatus as recited in Claim 45, wherein the twisted pair telephone line uses a
2 transmission protocol selected from the group consisting of Asymmetric Digital
3 Subscriber Line (ADSL), G.Lite and Very High Bit Rate DSL (VDSL).

1 61. An apparatus for determining coefficients for use in a filter to process data received
2 from a communications channel comprising:
3 means for determining a communications channel transfer function based on the
4 received data;
5 means for determining a noise power spectral density based on the received data;
6 means for determining a communications channel impulse response based on the
7 communications channel transfer function;
8 means for determining a noise covariance based on the noise power spectral density;
9 and
10 means for determining the coefficients based on the communications channel impulse
11 response and the noise covariance.

1 62. The apparatus as recited in Claim 61, wherein the means for determining the
2 communications channel transfer function includes:
3 means for accumulating a plurality of symbol values based on the received data;
4 means for determining an average received symbol value based on the received data;
5 and
6 means for determining the communications channel transfer function based on the
7 plurality of symbol values and the average received symbol value.

1 63. The apparatus as recited in Claim 61, wherein the means for determining the noise
2 power spectral density includes:
3 means for measuring a plurality of symbol values based on the received data;
4 means for determining an average received symbol value based on the received data;
5 and
6 means for determining the noise power spectral density based on the plurality of
7 symbol values and the average received symbol value.

1 64. The apparatus as recited in Claim 61, wherein the means for determining the
2 communications channel impulse response includes:
3 means for determining the communications channel impulse response based on an
4 inverse fast Fourier transform (FFT) of the communications channel transfer
5 function.

1 65. The apparatus as recited in Claim 61, wherein the means for determining the noise
2 covariance includes:
3 means for determining the noise covariance based on an inverse fast Fourier
4 transform (FFT) of the noise power spectral density.

1 66. The apparatus as recited in Claim 61, wherein the means for determining the
2 coefficients includes:
3 means for forming two matrices based on the communications channel impulse
4 response and the noise covariance;
5 means for generating a quadratic expression based on the two matrices; and
6 means for minimizing the quadratic expression to determine the coefficients.

1 67. A method for generating coefficient data comprising the computer-implemented step
2 of generating coefficient data that represents a set of one or more coefficients that are
3 selected based on noise power and an impulse response of a communications channel
4 when the coefficients are used with an algorithm to equalize received data from the
5 communications channel, wherein the received data is based upon both modulated
6 data and noise and the modulated data is the result of original data modulated onto
7 one or more carriers.

1 68. A computer-readable medium carrying coefficient data that represents a set of one or
2 more coefficients that are selected based on noise power and an impulse response of a
3 communications channel when the coefficients are used with an algorithm to equalize
4 received data from the communications channel, wherein the received data is based
5 upon both modulated data and noise and the modulated data is the result of original
6 data modulated onto one or more carriers.

1 69. An apparatus for generating coefficient data comprising:
2 a storage medium for storing the coefficient data; and
3 a coefficient generator configured to generate the coefficient data, wherein the
4 coefficient data represents a set of one or more coefficients that are selected
5 based on noise power and an impulse response of a communications channel
6 when the coefficients are used with an algorithm to equalize received data
7 from the communications channel, wherein the received data is based upon
8 both modulated data and noise and the modulated data is the result of original
9 data modulated onto one or more carriers.